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RELATIONSHIPS BETWEEN NORTH AMERICAN TURTLES OF THE *CHRYSEMYS* COMPLEX AS INDICATED BY THEIR ENDOPARASITIC HELMINTHS

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Abstract.—Comparisons of the similarity indexes of helminth faunas parasitizing North American species of the turtle genera *Chrysemys*, *Pseudemys*, and *Graptemys* indicate that these turtles represent three separate genera. *Pseudemys* species apparently are not congeneric with *Chrysemys picta* as suggested by other studies. Also, the species of *Graptemys* appear more closely related to *Pseudemys* than to *Chrysemys picta*.

McDowell (1964) revised the New World emydine genus *Chrysemys* on the basis of skull and foot morphology, including in it *C. picta* and the slider turtles of the genus *Pseudemys*, and suggested that three subgenera were involved (*Chrysemys*, *Pseudemys*, and *Trachemys*). Similarities in the choanal structure of *Chrysemys picta* and various species of *Pseudemys* upheld both the placement of the *Pseudemys* within the genus *Chrysemys* and McDowell's subgeneric distinctions (Parsons 1968). Zug (1966) found little variation in the penial structure of *Chrysemys picta* and *Pseudemys scripta, P. nelsoni, P. floridana,* and *P. concinna,* strengthening the inclusion of these turtles within *Chrysemys*. Weaver and Rose (1967) concurred with the inclusion of *Pseudemys* in *Chrysemys,* but showed the subgenera to be invalid, basing this on further examination of skull and shell characters.

Ernst and Barbour (1972), Conant (1975), and the Testudines Section of the *Catalogue of American Amphibians and Reptiles* (Society for the Study of Amphibians and Reptiles), of which the senior author is editor, recognize *Graptemys* and *Chrysemys*. There remains much disagreement about the generic arrangement of these turtles and many experts still maintain that *Pseudemys* is a separate genus.

Recently, Holman (1977) expressed doubts about the status of McDowell's (1964) genus *Chrysemys*. Holman points out that under McDowell's concept as many as four species may occur in the same water body in the southeastern United States and that, although they have similar courtship patterns, there are no records of hybridization between *Chrysemys picta* and other species of *Chrysemys*. However, hybrids are known within the subgenus *Pseudemys*: *C. floridana* × *C. concinna* (Smith, 1961)

Table 1.—Similarity indexes of the helminth faunas of North American *Chrysemys*, *Pseudemys*, and *Graptemys*.

	Chrysemys picta	*Pseudemys* (generic)	*Pseudemys scripta*	*Graptemys* (generic)
Chrysemys picta	—	50.0	48.2	38.7
Pseudemys (generic)	50.0	—	95.1	43.9
Pseudemys scripta	48.2	95.1	—	46.8
Graptemys (generic)	38.7	43.9	46.8	—

and *C. floridana* × *C. rubriventris* (Crenshaw, 1965). Holman (1977) urged additional study of the relationships within the genus. Consequently, the morphological, cytological, and biochemical characteristics are being re-evaluated by investigators at the Carnegie Museum (Richard C. Vogt, pers. comm.).

We decided to approach the problem by comparing the species of endoparasitic helminths hosted by these turtles (see Ernst and Ernst, 1977; Rosen and Marquardt, 1978), excluding those helminths known only from experimental infections and those extralimital to *Chrysemys picta*, a species that is restricted to North America.

The helminths that parasitize any host are, in a sense, among the characteristics of that host (Manter, 1966). The fact that a certain species of turtle acts as the host of certain helminths characterizes that species of turtle just as do its morphological, cytological, or biochemical traits. Once established in a host, both the parasite and host evolve as a unit, while also undergoing their independent evolution. In time a given endoparasite becomes specifically adapted to the internal environment of its host species and it may not mature and survive except in that host, or in closely related species. Such host specificity may be used to show closeness of kinship between related species and is useful in determining phylogenetic affinities of hosts.

Materials and Methods

Table 3 lists the endoparasitic helminths known to occur in *Chrysemys picta*, the genus *Pseudemys*, *Pseudemys* (*Trachemys*) *scripta* (the species thought most closely related to *C. picta*), and the genus *Graptemys*, a third closely related genus (Ernst and Barbour, 1972).

Since the successful parasite is adapted to the ecological conditions of its microhabitat within the host, each host can be treated as a separate ecosystem. The methods of describing the relationships of species composition between ecosystems vary widely. One approach is comparisons based on

Table 2.—Similarity indexes of the helminth faunas of North American *Chrysemys*, *Pseudemys*, and *Graptemys*. A = excluding the trematodes *Polystomoides coronatum*, *Heronimus mollis*, and *Telorchis corti*, and the nematodes *Camallanus microcephallus*, *Spiroxys constrictus*, and *S. contortus*. B = excluding the same trematodes and nematodes and all acanthocephalans.

	Chrysemys picta		*Pseudemys* (generic)		*Pseudemys scripta*		*Graptemys* (generic)	
	A	B	A	B	A	B	A	B
Chrysemys picta	—	—	42.1	40.0	39.4	36.7	24.0	22.2
Pseudemys (generic)	42.1	40.0	—	—	94.5	93.3	34.3	33.3
Pseudemys scripta	39.4	36.7	94.5	93.3	—	—	36.9	36.4
Graptemys (generic)	24.0	22.2	34.3	33.3	36.9	36.4	—	—

diversity indexes. Sorensen's (1948) Index of Similarity is best suited for mathematically expressing the generic relationships of the helminth faunas of *Chrysemys*, *Pseudemys*, and *Graptemys*. To investigate the degree of similarity of the helminth faunas of each pair of genera, and between *C. picta* and *P. scripta*, all possible pairings were tested. The system of notation is

$$S = \frac{2C}{A + B} \times 100$$

where A = the number of helminth species in host A, B = the number of helminth species in host B, and C = the number of helminth species common to both hosts. Identity of host ecosystems is recorded as 100, and closely related, but not identical, hosts should show indexes approaching 100. The less closely related are the two hosts, the lower is the index.

Results

Table 1 presents the similarity indexes for all comparisons. The helminth fauna of *Pseudemys scripta* is similar (95.1) to the total helminth fauna reported from all of the North American members of the genus *Pseudemys* (McDowell's subgenus *Pseudemys*). This high index is indicative of closely related congeneric species which provide similar internal ecosystems for helminths. But *Chrysemys picta* has no index higher than 50.0 when compared with the total North American *Pseudemys*, and only a 48.2 index with *P. scripta*, with which it is thought to be most closely related. Present evidence suggests that *Chrysemys* and *Pseudemys* are sufficiently different to warrent recognition at the generic level. Also, the indexes given in Table 1 indicate that *Graptemys* is a separate genus.

Table 3.—Helminth faunas of North American *Chrysemys*, *Pseudemys*, and *Graptemys* (from Ernst and Ernst 1977, and Rosen and Marquardt 1978). + = present, − = absent.

	Chrysemys picta	*Pseudemys* (generic)	*Pseudemys scripta*	*Graptemys* (generic)
I. Monogenetic trematodes				
1. *Neopolystoma orbiculare*	+	+	+	−
2. *Polystomoidella hassalli*	−	+	+	−
3. *Polystomoidella oblongum*	+	+	+	−
4. *Polystomoides coronatum*	+	+	+	+
5. *Polystomoides multifalx*	−	+	−	−
6. *Polystomoides oris*	+	−	−	−
II. Digenetic trematodes				
1. *Allassostoma magnum*	−	+	+	−
2. *Allassostomoides chelydrae*	+	−	−	+
3. *Allassostomoides parvum*	+	+	−	−
4. *Auridostomum chelydrae*	+	−	−	−
5. *Cephalogonimus compactus*	−	+	−	−
6. *Cephalogonimus vesicaudus*	−	+	+	+
7. *Cotylaspis cokeri*	−	−	−	+
8. *Dictyangium chelydrae*	−	+	+	+
9. *Eustomos chelydrae*	+	−	−	−
10. *Henotosoma elephantis*	+	−	−	−
11. *Henotosoma haemotobium*	+	−	−	−
12. *Heronimus mollis*	+	+	+	+
13. *Macrovestibulum eversum*	−	−	−	+
14. *Macrovestibulum kepneri*	−	+	+	−
15. *Macrovestibulum kraatzi*	−	+	−	−
16. *Macrovestibulum obtusicaudum*	−	+	+	+
17. *Microphallus opacus*	+	−	−	+
18. *Pneumatophilus variabilis*	−	+	+	−
19. *Protenes angustus*	+	+	+	−
20. *Spirorchis artericola*	+	+	+	+
21. *Spirorchis blandingioides*	−	+	+	−
22. *Spirorchis elegans*	+	+	+	−
23. *Spirorchis innominatus*	+	+	−	+
24. *Spirorchis parvum*	+	−	−	−
25. *Spirorchis pseudemydae*	+	+	+	−
26. *Spirorchis scripta*	+	+	+	+
27. *Telorchis attenuatus*	+	−	−	−
28. *Telorchis corti*	+	+	+	+
29. *Telorchis diminutus*	−	+	+	−
30. *Telorchis gutturosi*	−	−	−	+
31. *Telorchis nectori*	−	−	−	+
32. *Telorchis nematoides*	+	+	+	−
33. *Telorchis robustus*	+	+	+	−
34. *Telorchis singularis*	−	+	+	−
35. *Unicaecum dissimile*	−	+	+	−
36. *Unicaecum ruszkowskii*	−	+	+	+

Table 3.—Continued.

	Chrysemys picta	*Pseudemys* (generic)	*Pseudemys scripta*	*Graptemys* (generic)
III. Cestodes				
1. *Proteocephalus testudo*	−	+	+	+
IV. Acanthocephalans				
1. *Leptorhynchoides* sp.	−	+	+	−
2. *Neoechinorhynchus chelonos*	−	+	+	−
3. *Neoechinorhynchus chrysemydis*	+	+	+	−
4. *Neoechinorhynchus emydis*	+	+	+	+
5. *Neoechinorhynchus emyditoides*	−	+	+	−
6. *Neoechinorhynchus magnapapillatus*	−	+	+	−
7. *Neoechinorhynchus pseudemydis*	+	+	+	−
8. *Neoechinorhynchus stunkardi*	−	+	+	+
V. Nematodes				
1. *Aplectana* sp.	+	+	+	−
2. *Camallanus microcephallus*	+	+	+	+
3. *Chelonidrancunculus* sp.	−	+	+	−
4. *Cissophyllus penitus*	−	+	+	−
5. *Cosmocercoides dukae*	−	−	−	+
6. *Cucullanus cirratus*	−	+	+	−
7. *Filaria* sp.	+	−	−	−
8. *Gnathostoma procyonus*	−	+	+	+
9. *Hedruris armata*	+	−	−	−
10. *Icosiella quadrituberculata*	−	+	+	−
11. *Oswaldocruzia leidyi*	−	−	−	+
12. *Oxyuroides* sp.	−	+	+	−
13. *Physaloptera* sp.	+	−	−	−
14. *Spironoura* sp.	+	+	+	−
15. *Spironoura affinis*	−	+	+	+
16. *Spironoura chelydrae*	−	+	+	−
17. *Spironoura concinnae*	−	+	+	+
18. *Spironoura gracilis*	−	+	+	−
19. *Spironoura procera*	−	+	+	−
20. *Spironoura wardi*	−	−	−	+
21. *Spiroxys constrictus*	+	+	+	+
22. *Spiroxys contortus*	+	+	+	+

Discussion

The number and variety of endoparasitic helminths which any host may have depends on favorable environmental conditions permitting contact between the final host and the infective stages of the parasite. This requires hosts to live in similar habitats (in this case, water bodies) and to feed on similar foods.

Use of the same water body occurs at Reelfoot Lake, Tennessee, where

Chrysemys picta, three species of *Pseudemys,* and at least two of *Graptemys* are sympatric. Also, Ernst (1971) and Moll (1973) have commented on apparent competition between *C. picta* and *P. scripta.* Thus, habitat differences alone cannot account for the low comparison indexes.

Chrysemys picta and the species of *Pseudemys* have similar feeding habits (Ernst and Barbour, 1972). They are carnivorous as juveniles, but become more herbivorous with age, eating many of the same animals and plants. Food habits do not explain their low parasite similarity. The species of *Graptemys* have different food preferences, being essentially insect or mollusk eaters, and this may result in the low similarity indexes with the other turtle groups.

This study assumes that all types of helminths are host specific. This is probably true of most species included in this study. Cestodes are definitely host specific (Baer, 1971). Many monogenetic and digenetic trematodes are specific as to their definitive host but others are not, and while these are specific to intermediate hosts, they depend more on the feeding habits of the final host (Manter, 1966). A similar situation may occur in some nematodes (Baer, 1971). *Polystomoides coronatum, Heronimus mollis, Telorchis corti, Camallanus microcephallus, Spiroxys constrictus,* and *S. contortus* parasitize *C. picta, Pseudemys, Graptemys* and many other species of turtles of several families (Ernst and Ernst, 1977), and probably fall into these latter groups. However, if these parasites are eliminated from the index calculations, the results are similar (Table 2) to those obtained earlier. This is also true if the turtle acanthocephalans are eliminated, which Fisher (1960) and Rosen and Marquardt (1978) feel are not sufficiently host specific (Table 2).

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